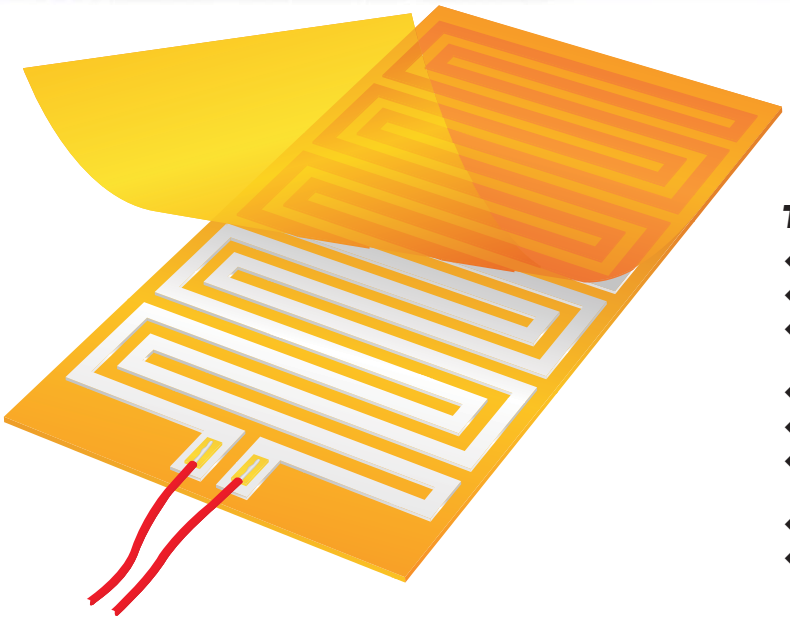
Contents

Thermofoil™ Solutions for Heating



Thermofoil™ etched foil heaters

- Foil element
- Uniform heat patterns
- Permits complex shapes and profiled heat patterns
- Thin, small bend radius
- Small sizes
- Many insulation options (Kapton™, silicone rubber, mica, polyester, PTFE)
- High watt density
- Welded leadwires

Thermofoil heaters are thin, flexible heating elements consisting of an etched foil resistive element laminated between layers of flexible insulation. Since their introduction by Minco over 25 years ago, Thermofoil heaters have demonstrated significant advantages over conventional electric heaters:

Precise heating

Thermofoil heaters put heat where you need it. You simply apply them to the surface of the part to be heated. Their thin profile gives close thermal coupling between the heater and heat sink. You can even specify profiled heat patterns higher watt densities in areas where heat loss is greater.

Faster warmup and longer life

The flat foil element of Thermofoil heaters transfers heat more efficiently, over a larger surface area, than round wire. Thermofoil heaters therefore develop less thermal gradient between the resistive element and heat sink. Heaters stay cooler. The result is higher allowable watt densities, faster warmup, and prolonged insulation life. Thermofoil heaters can safely run at wattages twice those of their wire-wound equivalents. Insulation life may be ten times greater. For high levels of reliable heat, the obvious choice is Thermofoil.

Space and weight savings

A Kapton heater typically weighs only 0.009 oz/in^2 (0.04 g/cm^2) and measures just 0.010" (0.25 mm) thick over the element. For applications with little room for a conventional heater — satellites and spacecraft, airplanes, portable instruments, high density electronic devices — Thermofoil heaters pack the heat in.

Custom tailored for better fit

Size and shape possibilities are limitless. Minco has built heaters as large as 18 feet long, and as small as 0.25" square. You can specify intricate geometries to follow the bumps and curves of your hardware. Computer aided design produces uniform or profiled heating elements to meet your precise needs.

Integral temperature sensors

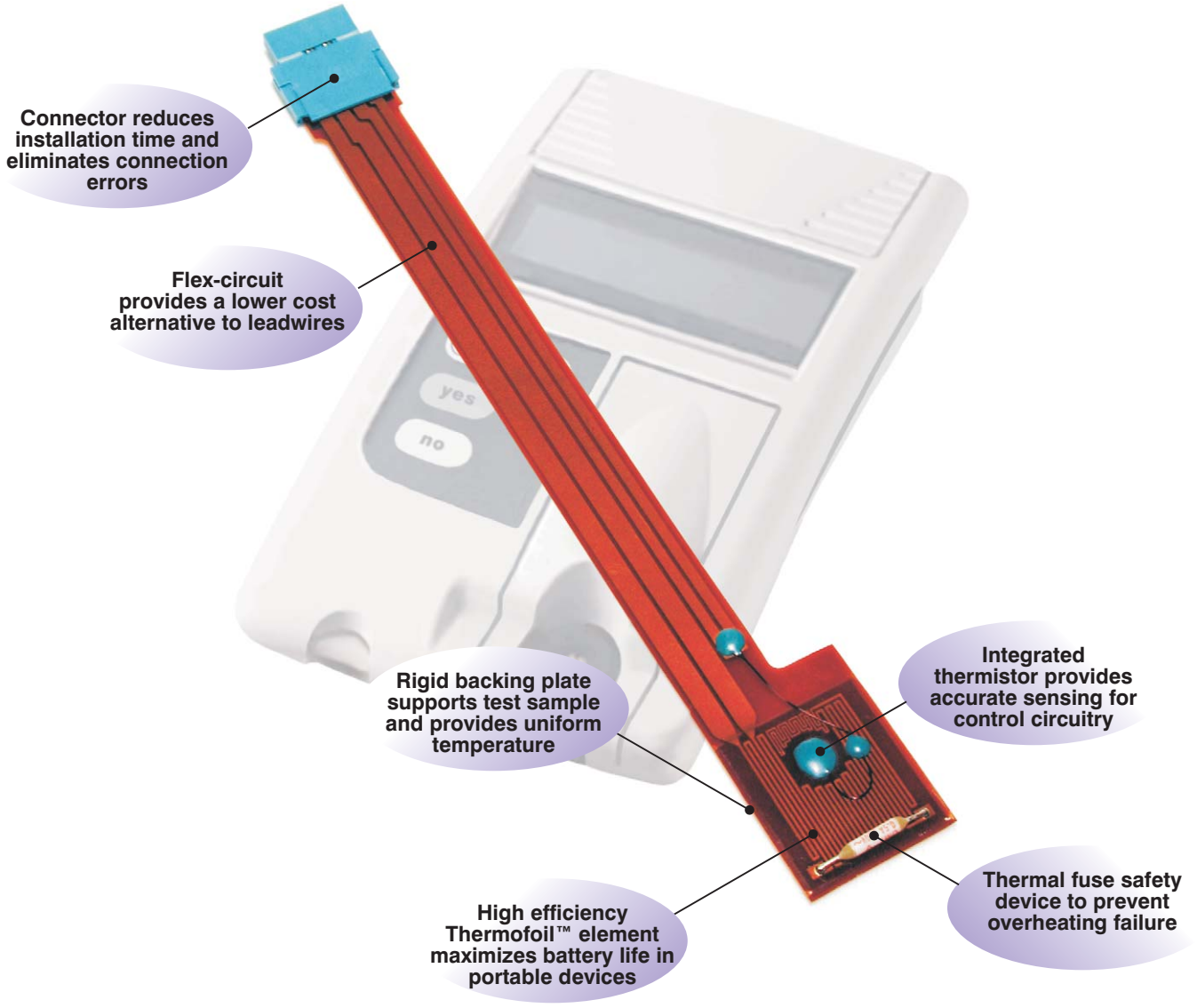
Minco is a leading manufacturer of temperature sensors and instruments. We can furnish heaters with integral resistance thermometers, thermocouples, thermistors, or thermostats. Minco controllers link sensors and heaters.

Heater subassemblies

As an added service, Minco can laminate, vulcanize, or clamp heaters to mating metal parts. Our specialized equipment guarantees tight bonds, high reliability, and superior performance. We mount the heater to your furnished parts, or fabricate heat sinks in our modern machine shop.

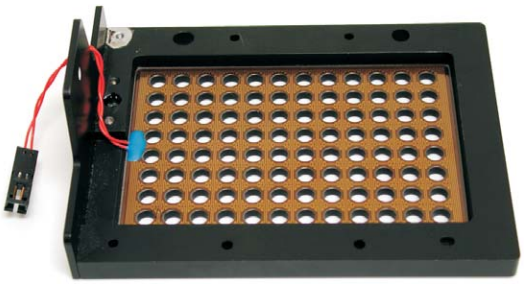
Thermofoil™ Solutions for Heating

When a leading manufacturer of medical diagnostic equipment needed a special heater design, they came to Minco . . .



. . . and working together, we created a solution that reduced cost, improved reliability, and helped launch a successful product.

DNA testing

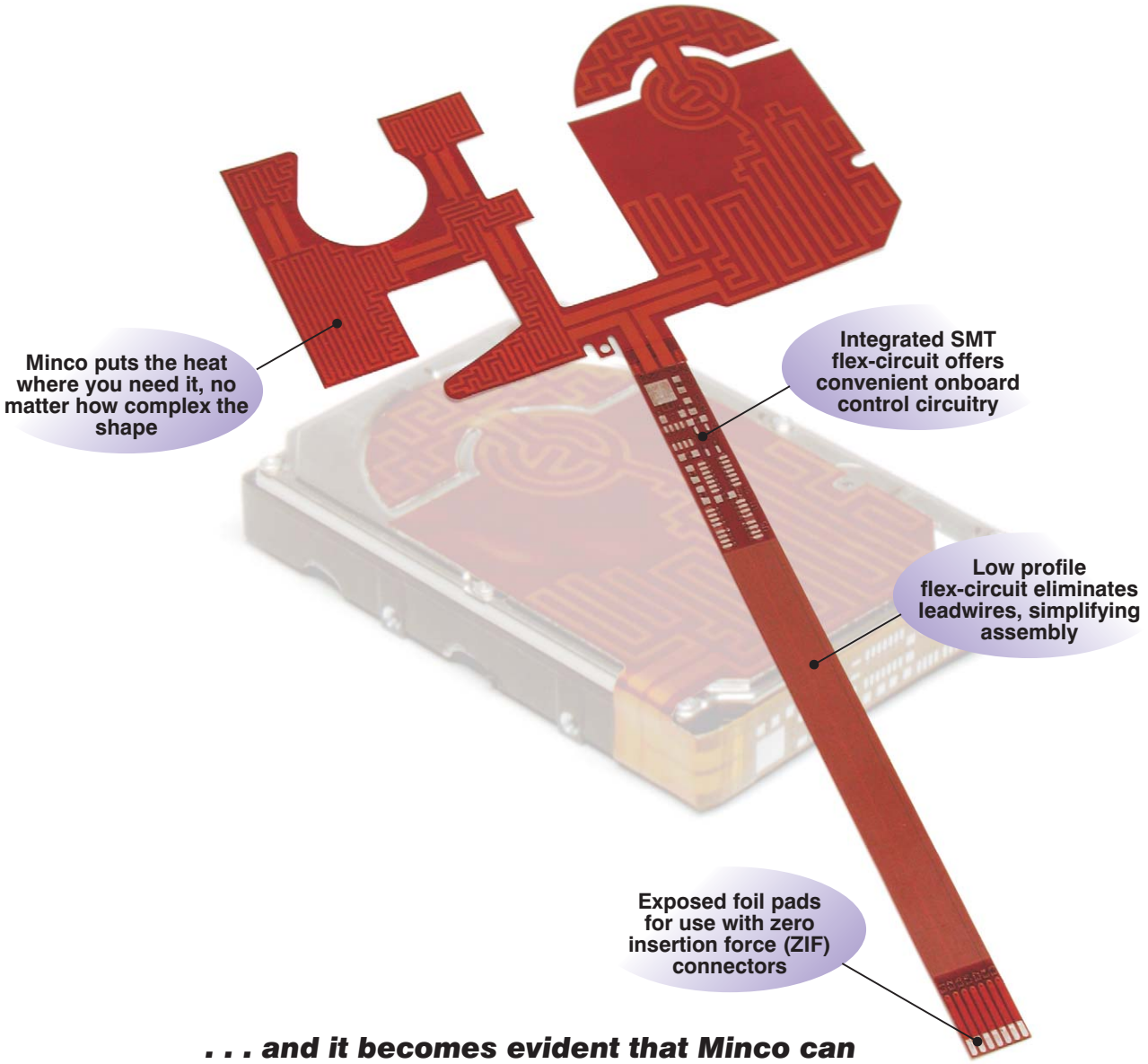


Respirator

Sample vial

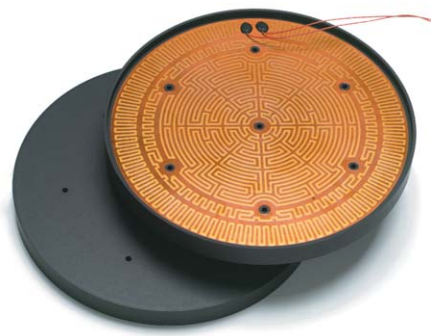
Thermofoil™ Solutions for Heating

With a 3-dimensional approach to heating design, the possibilities are endless. Add to that the ability to integrate temperature sensors, flexible circuits, and SMT control electronics . . .

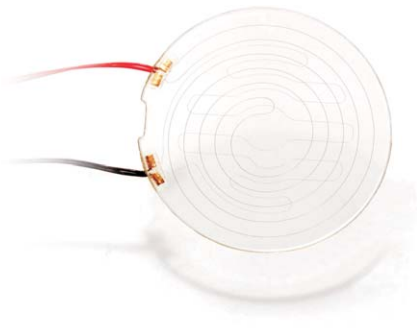


. . . and it becomes evident that Minco can provide a solution to nearly any heating problem.

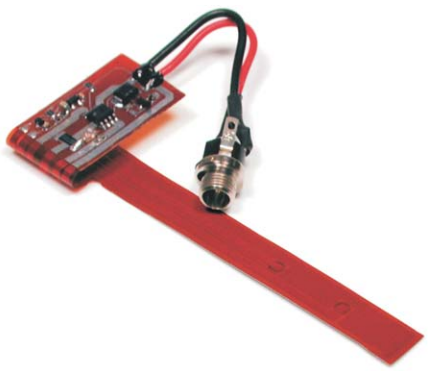
Heated chucks



Cockpit instrumentation

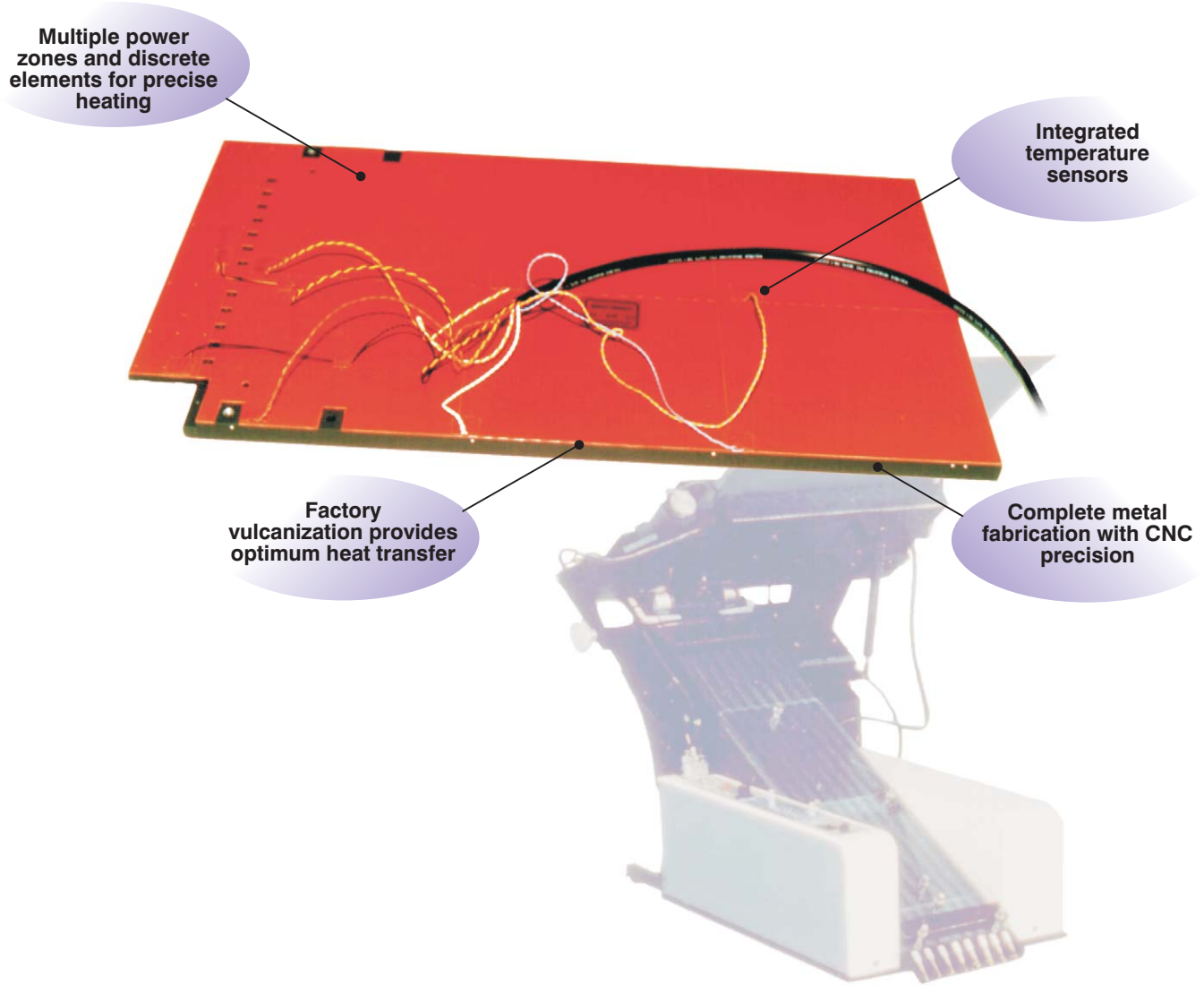


Industrial computing



Thermofoil™ Solutions for Heating

High volume testing machines for IC's require the best thermal performance with minimum down-time . . .

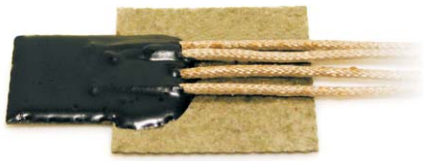


. . . Minco's complete assemblies include heating, sensing, protection and cables suitable for factory floor conditions.

Large motors

Food trays

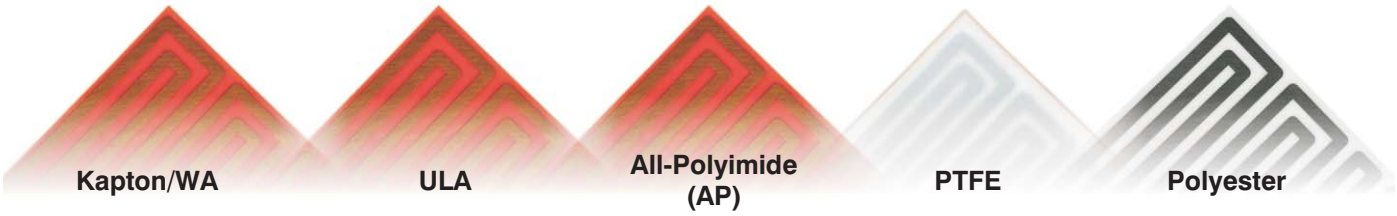
Chemical analyzers



Heater Insulations

Standard catalog insulations

Material	Temperature range	Max. size	Max. resistance density*	Comments
Kapton/FEP	-200 to 200°C -328 to 392°F	10" × 22" 250 mm × 560 mm	50-450 Ω/in² 8-70 Ω/cm²	See section B & D
Silicone rubber	-45 to 235°C -50 to 455°F	22" × 72" 560 mm × 1825 mm	200 Ω/in² 31 Ω/cm²	See section C & D (foil type) See section E (wire-wound type)
Mica	-150 to 600°C -238 to 1112°F	22" × 46" 560 mm × 1160 mm	11.5 Ω/in² 1.8 Ω/cm²	See section F
Optical grade polyester	-55 to 120°C -67 to 248°F	22" × 22" 560 mm × 560 mm	600-1200 Ω/in² 93-185 Ω/cm²	See section G



Alternative insulations (custom designs)

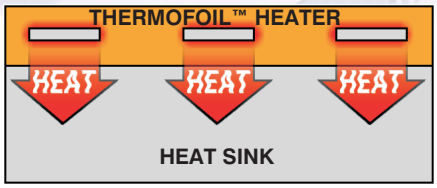
Material	Temperature range	Max. size	Max. resistance density*	Comments
Kapton/WA Polyimide film with acrylic adhesive	-200 to 150°C -328 to 302°F	22" × 72" 560 mm × 1825 mm	50-1500 Ω/in² 8-230 Ω/cm²	Similar to Kapton/FEP except lower cost, higher resistance densities, and lower temperature range. WA is preferred over FEP for most custom designs under 150°C.
ULA Polyimide film with UL recognized acrylic adhesive	-200 to 150°C -328 to 302°F	22" × 72" 560 mm × 1825 mm	50-1500 Ω/in² 8-230 Ω/cm²	Similar to Kapton/WA except UL recognized (UL94V-0).
All-polyimide (AP) Polyimide film with polyimide adhesive	-200 to 260°C -328 to 500°F (to 300°C for short periods)	22" × 22" 560 mm × 560 mm	50-1500 Ω/in² 8-230 Ω/cm²	Higher temperatures and watt densities than standard Kapton construction at greater cost. Typical applications include semiconductor processing and laboratory equipment.
PTFE*	-200 to 260°C -328 to 500°F	10" × 40" 254 mm × 1016 mm	50-450 Ω/in² 8-70 Ω/cm²	Fully sealed construction suitable for immersion in acids, bases, and other corrosive chemicals.
Polyester	-55 to 100°C -67 to 212°F	22" × 90" 560 mm × 2285 mm	50-300 Ω/in² 8-45 Ω/cm²	Low cost material for economic fabrication of large heaters.

* Resistance density varies with the size of the heater (higher density possible with smaller heaters).

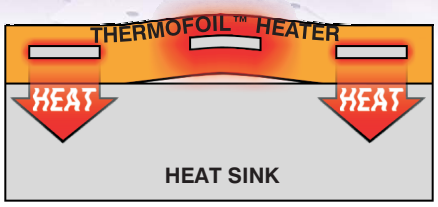
Heater Installation

Versatile Thermofoil™ heaters allow a variety of mounting methods.

Proper installation is crucial to heater performance. The heater must be in intimate contact with surface beneath, as any gaps can block heat and cause a hot spot.



Proper installation ensures good heat flow from the heater to the heat sink.



Voids or bubbles beneath the heater cause localized hot spots.

Pressure-sensitive adhesive (PSA) and #17 film

With factory-applied PSA, you simply remove the backing paper and press the heater in place.

#17 film for Kapton heaters requires high temperature and pressure to cure.

Description	Temperature rating	Comments	Installation instruction*
Acrylic PSA 0.002" (0.05 mm) acrylic film	See heater ordering information	♦ NASA approved for outgassing ♦ Flat surfaces only, unless aluminum backed	EI 138
#12 PSA 0.002" (0.05 mm) silicone film		♦ Flat or slightly curved surfaces	EI 266
#17 film 0.001" (0.03 mm) acrylic film (replaces #14 film)	-200 to 150°C -328 to 302°F	♦ NASA approved for outgassing ♦ Laminate at 160°C and 250 psi (17 bar)	EI 503

Epoxy and cement

Liquid adhesives require more care in application than PSA, but generally provide higher temperature/wattage performance.

Description	Temperature rating	Comments	Installation instruction*
#6 RTV cement Room temperature vulcanizing silicone for rubber heaters	-45 to 235°C -49 to 455°F	♦ Distance from center of heater to edge must be less than 5" (127 mm) ♦ 3 oz. tube covers 800-1300 in² (5000-8000 cm²)	EI 117
#15 epoxy 2-part epoxy for Kapton heaters	-70 to 115°C -94 to 239°F	♦ NASA approved for outgassing ♦ Bi-pack covers 150-300 in² (900-1800 cm²)	EI 507

Easy installation methods for cylindrical surfaces

Shrink bands are pre-stretched strips of film with adhesive coated ends. Wrap around the heater and heat to shrink. Stretch tape installs quickly with no heat required.

Description	Temperature rating	Comments	Installation instruction*
BM3 shrink band Polyester strip	-73 to 149°C -100 to 300°F	♦ To order, specify band width and cylinder diameter	EI 103
BK4 shrink band Kapton strip	-73 to 177°C -100 to 350°F		
#20 stretch tape Self-fusing silicone tape	-51 to 200°C -60 to 392°F	♦ Comes in 6 or 36 foot rolls, 1" wide. Figure 25% overlap when calculating length required.	EI 124

*Installation instructions and AA #22 available at www.minco.com/support

Clamping

Mechanical clamping is required for mica heaters and optional for Kapton (not recommended for rubber). Ask for Minco Installation instruction EI 347.

Factory vulcanization and lamination

See page J-4 for information on high-performance bonding of heaters to mating parts.

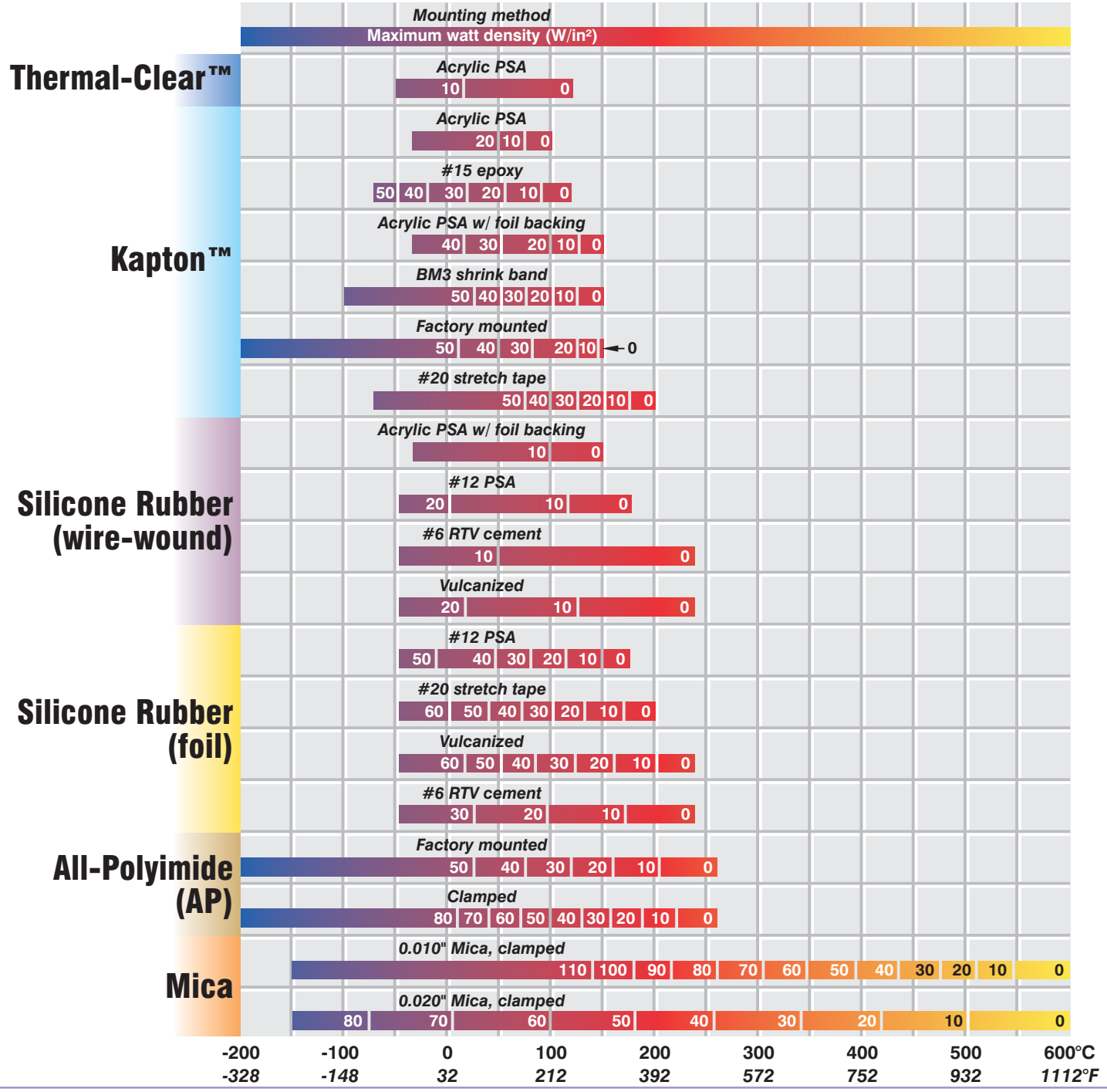
Maximum Watt Density

The power a heater can safely produce is limited by:

- The heater's insulation and internal adhesive
- The method used to install the heater
- The control temperature of the heat sink
- The area available for heating

Use the chart below to verify your selection of heater insulation and installation method with the required watt density:

1. Look up the effective area for the heater model in question. This is total heater area minus borders and lead attachment space (calculated by Minco).
2. Divide the power requirement in watts by this area to obtain watt density.
3. Draw a line from the heat sink temperature (at the top or bottom of the chart) to the colored bar labeled with the insulation and mounting method you have chosen.
4. The maximum watt density is indicated by the value printed in that segment of the colored bar. The individual sections of this catalog contain more detailed watt density charts.



Selecting a Catalog Heater

Calculating required wattage

The heater you select must produce enough power to (1) warm the heated object up to temperature in a specified time and (2) maintain that temperature.

The specific heat formula (page J-1) gives an estimate for warmup, assuming all heat enters the object and none is lost. Add at least 20% to account for unknown losses.

Heat loss factors include conduction, convection, and radiation. A more accurate wattage estimate will take these into account. For a general discussion of heat loss, request Minco Application Aid #21, "Estimating Power Requirements of Thermofoil Heaters." Also helpful is Thermal Calc, a free DOS program to assist with calculations (available at www.minco.com).

The best way to make a final determination of heat requirements is by experimentation. See page J-1 for tips, or request Application Aid #25, "Prototyping Techniques for Thermofoil™ Heaters."

Ohm's Law

A Thermofoil™ heater has a specific *resistance*. Its power output in watts depends on supply voltage ($W=E^2/R$).

R Ohms (Ω)			**P Watts (W)**			**I Amps (A)**			**E Volts (V)**		
$\frac{E}{I}$	$\frac{E^2}{P}$	$\frac{P}{I^2}$	EI	I^2R	$\frac{E^2}{R}$	$\sqrt{\frac{P}{R}}$	$\frac{P}{E}$	$\frac{E}{R}$	$\sqrt{PR}$	$\frac{P}{I}$	IR

Maximum wattage

The watt density tables on the following pages show the maximum allowable power for each heater type, expressed in watts per square inch of effective area. The rating depends on heater material, heat sink temperature, and the mounting method.

If wattage exceeds the maximum, the heater is in danger of burning up. Ways to obtain more power:

- Specify a larger size heater.
- Consider other heater materials, e.g. mica.
- Change the mounting method.
- Use proportional control to reduce power as the heat sink temperature rises. This requires a short controller cycle time and a fast responding sensor.
- Contact Minco for design assistance.

In addition to wattage, you should calculate the current (I) through the heater leadwires to keep it within the maximum rating for that AWG size.

Heater selection examples

Desired temperature	60°C	100°C	100°C (same as left)	150°C
Power required	300 W at 115 V	500 W at 240 V		2500 W at 480 V
Heater size	3" × 6"	2" × 10"		9" diameter
Ideal resistance	$115^2/300 = 44.1\ \Omega$	$240^2/500 = 115\ \Omega$		$480^2/2500 = 92.2\ \Omega$
Mounting method	#3 shrink band	#6 RTV cement	Factory vulcanized	Clamped
Model chosen	HK5468 R46.1 L12 A	HR5430 R96.8 L12 A		HM6810 R83.4 L12 T2
Effective area	15.74 in²	18.20 in²		58.5 in²
Actual power	$115^2/46.1 = 287$ W	$240^2/96.8 = 595$ W		$480^2/83.4 = 2762$ W
Watt density	287/15.74 = 18 W/in²	595/18.20 = 33 W/in²		2762/58.5 = 47 W/in²
Max. watt density	36 W/in² at 60°C	19 W/in² at 100°C	36 W/in² at 100°C	54 W/in² at 150°C
Wattage OK?	Yes (18 < 36)	No! (33 > 19)	Yes (33 < 36)	Yes (47 < 54)
Leadwire current	115/46.1 = 2.5 A	240/96.8 = 2.5 A		480/83.4 = 5.8 A
Current OK?	Yes (2.5 < 7.5)	Yes (2.5 < 5.0)		Yes (5.8 < 11.0)